MARS ENVIRONMENT CHAMBERS IN NASA GODDARD’S PLANETARY ENVIRONMENTS LAB.

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Introduction: The Planetary Environments Lab (PEL) at NASA’s Goddard Space Flight Center (GSFC) is home to two Mars environment instrument test facilities. One of the Mars chambers is used for the Sample Analysis at Mars (SAM) investigation instrument suite on the Curiosity rover, and currently houses the SAM Testbed (TB) instrument. The other chamber is used for the Mars Organic Molecule Analyzer (MOMA) scheduled to launch on the ESA ExoMars rover in 2018.

Each chamber was designed to test the instruments in Mars-like conditions, providing high fidelity boundary conditions with interfaces developed to recreate how the instruments are mounted in their respective spacecraft. Mars thermal and atmospheric conditions inside the chambers can be adjusted to match the diurnal and seasonal variations found at Gale Crater, and any of the candidate landing sites of ExoMars.

The flexibility of these chambers allows for a wide range of tests to faithfully characterize and diagnose instrument performance in Mars conditions, without encumbering valuable flight resources on Mars.

SAM Mars Chamber Design: The SAM TB is a duplicate of the Flight Model (FM) currently onboard the Curiosity rover in Gale Crater, Mars. A detailed description of the SAM instrument can be found in [1]. The TB is operated in the SAM environmental chamber, Figure 1, which was designed to replicate the thermal and atmospheric conditions at Gale Crater.

Unlike traditional thermal vacuum (TVAC) systems, the SAM chamber was designed to operate at the nominal Mars surface pressure of approximately 8 mbar CO2, while also keeping cold Mars surface temperatures inside the chamber. Achieving the cold Mars boundary temperatures (~-80° C) while at 8 mbar CO2 was accomplished by using gold or electropolishing nickel plated thermal plates, and electropolishing all wall surfaces to reduce emmissivity. Cold nitrogen gas (GN2) is used to cool the panels, so as to not freeze out the CO2 atmosphere in the chamber.

Each of the panels in x, y, and z axes can be individually controlled to a different temperature, with a range of 150° C to -80° C, which allows for the SAM boundary conditions in the chamber to replicate each interface inside the rover body. Chamber pressure and temperature can also be varied based on diurnal and seasonal changes to best represent the current conditions of SAM on Mars.

Figure 1. SAM TB inside the Mars environment chamber at NASA GSFC, shown with open access door. The chamber was used for FM testing and continues to support critical mission operations.

SAM Chamber Use: The primary current use of the SAM TB is to develop and validate new and modified experimental procedures to be used on the FM. TB experiments are performed multiple times to ensure safe operation on Mars, as well as to optimize parameters to optimize science return. Once an experiment is ready for use on Mars, the exact script to be run on the FM is validated on the TB. The TB uses the same flight software and produces the exact same telemetry as the FM, precisely duplicating SAM experiments.

The TB is also used to analyze Mars analog materials under conditions as similar to those in the SAM FM runs as possible [2]. Mars analog samples are first analyzed using one or more benchtop laboratory systems configured to run under SAM-like conditions. The results of these experiments allow the SAM team to narrow down which samples will be analyzed in the more resource intensive SAM Testbed, the highest fidelity SAM-like system on this planet. These TB analog sample runs may have science or calibration (e.g., sample temperature calibration) rationales.

Both SAM FM and TB have internal standard calibrants, in the form of a gas mixture in an onboard cell, along with solid sample calibrants sealed in onboard cups. The calibrants on the TB and FM are identical, which ensure that any changes or differences in the
instruments are accounted for when designing experiments and trending instrument performance over time.

**Key SAM Experiments developed on TB:** New or modified experiments are developed and optimized using the SAM TB before execution on Mars. Using a high fidelity replica of the FM allows the SAM team to develop discovery-driven experiments targeted to specific science goals. This development process can take months depending on the complexity of the experiment, which translates to many hours of TB use.

SAM is an instrument of many ‘firsts’, such as the first in situ noble gas geochronology measurement on another planet [3], thanks in part to extensive testing and validation using the SAM TB. This experiment was not part of the original SAM investigation, but the flexibility of the TB allowed for this important new measurement to be developed, tested, and ultimately executed successfully on Mars.

Another ‘first’ was the use of static mass spectrometry, which ran the mass spectrometer in a mode using only a chemical getter as the pump. This static mode was the key development to measure the trace heavy noble gases in the atmosphere [4].

**MOMA Mars Chamber Design:** The MOMA chamber, shown in Figure 2, is an updated version of the SAM chamber, with modifications made to match the ExoMars rover interface conditions.

![Figure 2. Mars environment chamber for MOMA at NASA GSFC. The chamber is currently being used to test the FM scheduled for launch on the ExoMars rover in 2018.](image)

Like the SAM chamber, the MOMA chamber can vary the atmospheric pressure (down to <10^-7 mbar) and temperature (-60° C up to +150° C) to simulate the conditions at almost any latitude on Mars, including all four landing sites being considered on ExoMars. The primary landing zone candidate is in Oxia Planum between 16° and 19° north latitude at elevations near -3 km (MOLA aeroid), well above Gale crater resulting in somewhat lower average diurnal pressures than used for SAM. The MOMA chamber requires precise pressure control due to the dependence of the ambient laser desorption-based analytical tuning on the exact Mars pressure. With an internal volume of >20 ft³ (between thermal plates), the MOMA chamber will be leveraged for future Mars instrument development/qualification testing for ExoMars.

**MOMA Chamber Use:** The MOMA Mars chamber has been employed to test functional and verify mechanical requirements of the Qualification Simulation Model (QSM), a key NASA GSFC deliverable. The MOMA Sorbent trap testing with the QSM has also been performed in the chamber in order to validate contamination control and planetary protection procedures. The Mars chamber also enabled the Dry Heat Microbial Reduction (DHMR) processing of the MOMA QSM in situ. In the upcoming months, the performance of the MOMA FM will be characterized in this chamber to ensure full compliance of all functional requirements across the full range of temperatures and pressures expected on the ExoMars rover. After delivery of the FM, the MOMA TB will be treated similarly to the SAM TB, as an Earthbound instrument that can validate parameterized analytical protocols to be executed on the FM on Mars, as well as interpret mass spectra obtained with the FM on Mars by studying instrument behavior using analog samples from a growing library.

**Summary:** Mars environment chambers provide high fidelity thermal and atmospheric conditions in which to test flight instruments and subsequent testbed/engineering models. These TB instruments serve an invaluable role in supporting flight missions by serving as a way to validate and test new experiments, but to also ensure optimal science return without using valuable flight resources.

Analog testing on Earth can be done using conditions nearly identical to flight, accounting for any thermal changes in experiments that may arise. SAM TB data agree well with runs on other SAM-like laboratory systems or other ground truth measurements. SAM TB data from selected Mars analog materials, and comparisons to the results from other analyses of the samples, will be reported in a future manuscript.

Our team is interested in potential future collaborations to leverage the significant capabilities offered by the particular designs of these chamber facilities.


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